AD-A048 816 ARIZONA STATE UNIV TEMPE DEPT OF PSYCHOLOGY F/G 5/9
COGNITIVE PRETRAINING: AN AID IN THE TRANSITION FROM INSTRUMENT--ETC(U)
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UNCLASSIFIED AFHRL-TR-77-62 NL

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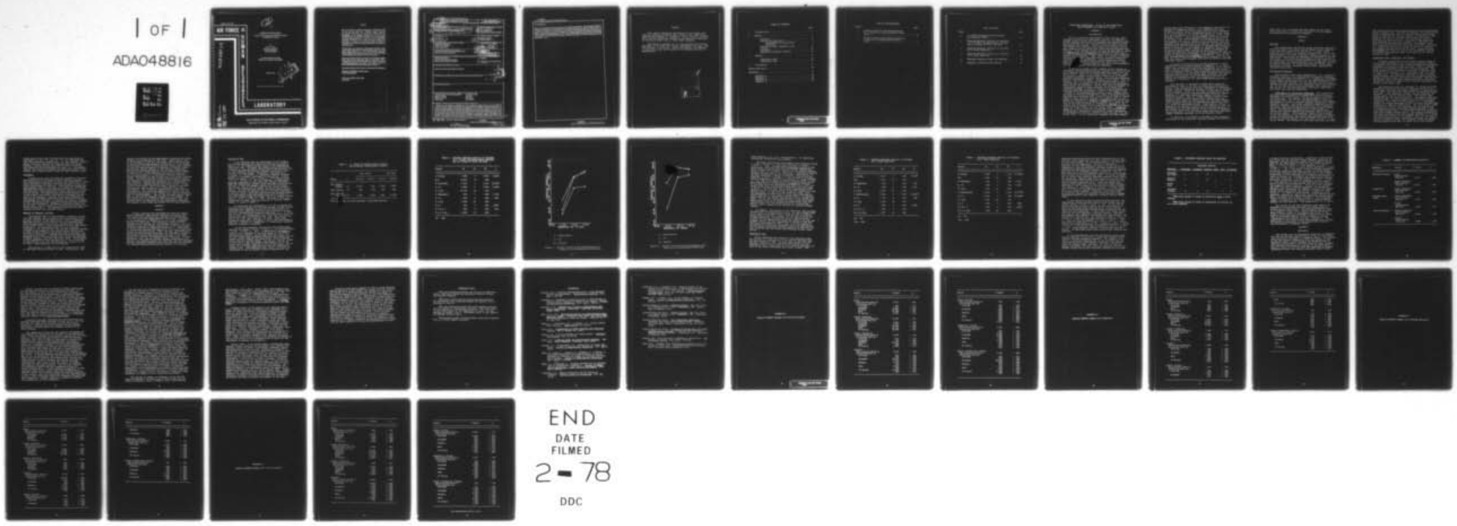

AFHRL-TR-77-62

AIR FORCE

HUMAN RESOURCES

COGNITIVE PRETRAINING: AN AID IN THE TRANSITION FROM INSTRUMENT TO COMPOSITE FLYING

By

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October 1977

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This final report was submitted by Arizona State University, Tempe, Arizona 85281, under contract F41609-75-C-0018, project 2313, with Flying Training Division, Air Force Human Resources Laboratory (AFSC), Williams Air Force Base, Arizona 85224. Mr. Gary B. Reid, Flying Training Research Branch, was the contract monitor.

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (18) AFHRL-TR-77-62

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) COGNITIVE PRETRAINING: AN AID IN THE TRANSITION FROM INSTRUMENT TO COMPOSITE FLYING,

5. TYPE OF REPORT & PERIOD COVERED (9) Final rept.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s) (10) John V. Crosby

8. CONTRACT OR GRANT NUMBER(s) (15) F41609-75-C-0018

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Department of Psychology
Arizona State University
Tempe, Arizona 85281

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
61102F
(16) 2313[redacted] (17) T5

11. CONTROLLING OFFICE NAME AND ADDRESS
HQ Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE (11) Oct[redacted]77

13. NUMBER OF PAGES ~~46~~ (12) 45p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Flying Training Division
Air Force Human Resources Laboratory
Williams Air Force Base, Arizona 85224

15. SECURITY CLASS. (of this report) Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Advanced Simulator for Pilot Training (ASPT)
audiovisual training
cognitive pretraining
flying training
good judgment skills
perception
pilot training
schema theory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was designed to investigate the role of cognitive pretraining relative to the early difficulties encountered by student pilots transitioning from ground-based instrument training to composite flying training. The cognitive pretraining consisted of: (a) an instrument reading review, (b) a vocabulary of relevant cockpit features, (c) the use of brief perceptual rules for pitch and bank attitudes, and (d) prototype representations of a variety of pitch and bank attitudes. Three groups of 12 pilots each participated in the study: student experimental, student control, and experienced instructor pilots (IP). The experimental group was exposed to cognitive pretraining and then compared to the student control and IP groups in a simulated composite flight laboratory task. Results of the laboratory task demonstrated superior discrimination performance of the student experimental group over both the over

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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student control and experienced pilot groups for the most difficult discrimination. As the discrimination difficulty decreased, the performance of the experimental and experienced pilot groups were equal and both were superior to the student control group. As a measure of the external validity of the laboratory task, both student groups were subjected to four discrete maneuvers in the Williams Air Force Base Human Resources Laboratory, Flying Training Division (AFHRL/FT) Advanced Simulator for Pilot Training (ASPT). Results of the ASPT task support the findings of the laboratory task. The laboratory and simulator results were discussed in the context of directed attention and schema theory.

PREFACE

This report represents the results of the flight attitude cue training conducted under Project 2313, USAF Flying Training Development, Dr. Herbert J. Colle, Project Scientist; Task 2313-T5 Information Processing and Cognitive Components of the Flying Task, Gary B. Reid, Task Scientist.

The author is grateful to all the military and civilian personnel at Williams AFB, AZ who unselfishly gave their time and interest to the study. These individuals, too numerous to name here, have been singled out in separate letters of appreciation.

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CHAPTER 1

Introduction

The U.S. Air Force Undergraduate Pilot Training (UPT) program at Williams Air Force Base, Arizona, is designed to provide student pilots with the academic and perceptual-motor skills necessary for the safe and proficient flying of high performance jet aircraft. Central to the concept of UPT is the concern that student pilots acquire and further develop good judgment skills rather than fixed stimulus-response connections. Good judgment skills can best be described in terms of adaptability and flexibility of performance based upon a variety of situational factors rather than a fixed network of generalizable responses. Wood (1973) in a survey of relevant learning hypotheses, suggested several possible dimensions influencing flying performance. These dimensions contain both cognitive and motor attributes and range from a clear understanding of the principles of the task to the possession of a motor program of the required responses.

In the early phases of UPT, student pilots receive instructions and task demonstrations together with opportunities for supervised practice in ground-based simulators (U.S. Air Force, 1975). Prior to the actual flying or "contact" phase of training, student pilots receive instruction on complex emergency procedures, cockpit checks, and instrument maneuvers such as "straight-and-level," "constant rate climb," "turn to heading," etc. It is during the instrument phase of pilot training that the student's initial cognitive and perceptual-motor skills are developed. During this early development or "instrument" phase of pilot training, the student pilot receives knowledge of results regarding task performance exclusively from the instruments. That is, the student pilot "attends to" and subsequently receives visual feedback from an array of aircraft instruments in what could essentially be described as a tracking task. Once in the aircraft or flying phase of pilot training, however, the student pilot is expected to function in a contact or composite mode and as such divide his attention in an 80:20 fashion; i.e., spend 80 percent of his time attending to information external to the cockpit and 20 percent of his time monitoring the instruments (U.S. Air Force, 1974a; U.S. Air Force, 1974b). Composite flight is a flying term used to describe the technique of using external references, supported by flight instruments, to establish and maintain aircraft flight attitude (U.S. Air Force, 1973). It is a generally accepted view that student

pilots experience difficulty in the transition from basic instrument to composite flying. It is believed that this difficulty results from the student pilot's early dependency on the instruments as the predominant source of visual feedback and the absence of a visual representation of the "view-from-the-cockpit." This new requirement of having to spend 80 percent of his time attending to information external to the aircraft and only 20 percent of his time monitoring the instruments is in direct conflict with his earlier training! Assuming these observations to be correct, the student pilot transitioning from the instrument, or ground-based simulation phase of training, to the contact or composite flying phase of training must somehow reorder his source of feedback information regarding the attitude of the aircraft from that solely obtained from instruments to an integrated or composite source of external and instrument information. That is, he must develop a cognitive representation or schema of the view from the cockpit and integrate this with his earlier acquired instrument skills.

If transition difficulties are due primarily to early dependence on a particular source of feedback; i.e., instruments, what effect would cognitive pretraining in the form of visual contact schemata have on the transition from instrument to composite flying? Would cognitive pretraining facilitate the transition by providing early conceptual information regarding the attitude of the aircraft as viewed from the cockpit and therefore assist the integration of the two sources of information? Or, would such pretraining be irrelevant?

This research is designed to probe those questions. Specifically, what is the role of cognitive pretraining as an aid in the transition from basic instrument to composite flying? Several hypotheses relevant to this line of research are of interest. First, if this type of pretraining is effective, then improved discrimination and reaction time performance in a contrived laboratory composite flight task should be evident. That is, student pilots receiving pretraining should perform better than a similar group of student pilots receiving conventional Air Training Command (ATC) Syllabus materials and approach the performance level of a group of experienced pilots. Additionally, and as a measure of the external validity of the laboratory task, the performance of the experimental group should be superior to the control group when required to fly a series of representative maneuvers in the Air Force Human Resources Laboratory (AFHRL) Advanced Simulator for Pilot Training (ASPT).

In addition to providing an estimate of the potential usefulness of the particular training concepts and materials

used, this line of research may have impact on the future design and use of instructional material in UPT instrument and composite flying training programs.

CHAPTER 2

Method

Subjects

The experimental and control groups were each composed of twelve Air Force UPT student pilots, drawn from Williams Air Force Base UPT classes 77-07 and 78-01. All were recent graduates of the Air Force Academy or West Point. Six of the twelve students from each class were randomly assigned to the experimental group with the remaining six assigned to the control group. The conditions prerequisite for participation in the study were that the student pilots have less than 50 hours of flying time, no previous rating (e.g., navigator), and not be foreign students. An additional external control group, consisting of twelve Instructor Pilots (IPs), provided experienced pilot data.

Pretraining Materials

The cognitive pretraining consisted of: (a) a review of instrument reading; (b) a description and feature vocabulary of the various canopy references; i.e., canopy bow, windscreen, glare shield, center bow, etc.; (c) the identification of the canopy references together with the vertical and horizontal reference planes depicting the conceptual nose of the aircraft, and (d) the aircraft attitude relationship with reference to the horizon for straight-and-level, left turn, right turn, nose high, and nose low conditions.

Development of Pretraining Materials. All pretraining materials were developed from operational flying training information extracted from a variety of sources at Williams Air Force Base. For example, the photographs of the T-37 instrument panel used in the instrument reading review were photographs of actual instrument readings used during landing approach training. The canopy reference vocabulary was obtained by randomly sampling 25 flight-line IPs to determine the modal terms used to describe the various cockpit references. The physical representation of the cockpit was constructed from photographs and sketches taken from within the actual cockpit. The conceptual "nose" of the aircraft or the intersection of the vertical and horizontal reference planes was constructed from verbal descriptions taken from Air Force Training manuals (U.S. Air Force, 1974a; U. S. Air Force, 1974b). The variety of nose high, nose low, and level

turn contact stimuli were generated using the above described stimuli together with interview information from research IPs. Prior to experimental use, the contact stimuli used in the study to describe the various aircraft attitudes were independently verified as accurate representations by five research and flight-line IPs. All pretraining materials were designed for self-paced instruction. Additional material for self-testing was included. Achievement tests were administered following self-paced instruction and prior to a laboratory testing to assess the degree of learning. No _a priori_ learning criterion was used. Black-and-white photographs were used for contact cue achievement testing. All pretraining materials were collected prior to the experimental task.

Laboratory Task, Apparatus, and Stimuli

To assess experimentally the student pilots' grasp of the concepts developed in the cognitive pretraining phase, a laboratory task consisting of tachistoscopically presented instrument and contact slides was used. First, a colored slide of the instrument panel was briefly displayed. The slide contained all information necessary to determine the attitude of the aircraft; i.e., nose high, nose low, left, or right turn. Following the instrument slide, a colored slide depicting the aircraft's attitude as viewed from the cockpit (contact slide) was briefly presented. The task of the subject was to determine whether the second slide was correct or incorrect, based on the attitude information contained in the first slide.

The laboratory task was performed in a sound and light attenuated room within the Flying Training Division, Air Force Human Resources Laboratory (AFHRL/FT) at Williams Air Force Base. The apparatus consisted of two modified tachistoscopes, a rear projection screen, correct/incorrect response levers, and an interval timer. The stimuli were separated into two broad categories: instrument slides and contact slides. Pitch and bank conditions were presented separately. The order of presentation; i.e., instrument/contact or contact/instrument as well as pitch and bank were balanced for order of presentation. The first slide, either instrument or contact, was presented for one second with a one-second interval being used between members of each instrument-contact pair. Four-second inter-trial intervals were used between adjacent pairs. The stimuli consisted of two broad categories with the _a priori_ probability of being correct being constant at 50 percent. That is, for each of the seven stimulus value conditions there were six correct and six incorrect slides. For example, if the instrument slide depicted wings level 0° pitch, six of the contact

slides were wings level 0° pitch while the remaining six described +2°, +4°, +6°, and -2°, -4°, -6° nose high and nose low conditions, respectively. In that fashion, psychometric data were obtained for straight-and-level pitch changes. Similar stimuli were used to obtain bank data. Each condition within presentation mode; i.e., instrument/contact and contact/instrument, was presented twice to each student for a total of four trials for each stimulus value.

Procedure

Student pilots were individually scheduled to minimize negative impact on any phase of their training program. The students were available following the completion of their basic instrument simulation training and prior to the aircraft flying phase of training. This scheduling window was approximately seven to ten days in duration and therefore required both subject and experimenter flexibility. During the laboratory task subjects were seated facing a rear projection screen. The experimenter was seated opposite and to the side of the subject and read the necessary instructions to the subject. Practice slides were presented to the subject and sample responses were requested to verify understanding of the task. A response of "correct" indicated that the second slide correctly represented the attitude of the aircraft based on information contained within the first slide. Once initiated the stimulus presentations were cycled automatically. Two dependent measures were taken, correct/incorrect and response latency.

Measure of External Validity

The USAF/HRL ASPT, a high-fidelity replication of the T-37 Jet Trainer, was utilized to obtain a measure of the external validity of the pretraining. ASPT is completely described by Bell (1974) and will not be discussed here. Both the experimental and control students were required to fly three trials of four maneuvers in each of two visual conditions: (a) instruments only, and (b) composite reference to the horizon with the attitude indicator covered. A rated IP was present in the cockpit and provided basic aircraft control related information before and after, but not during, maneuvers. Computer generated performance measurement data in the form of RMS error scores for altitude, airspeed, heading, and bank angle were taken. Additionally, at the completion of each discrete trial, the IP provided a single global score for the maneuver on a scale of 1 to 12, with 1 unsatisfactory and 12 excellent.

Both groups of student pilots were scheduled for ASPT in individual two-hour blocks of time. Upon arrival, the

subject was briefed by the experimenter regarding the scope, duration, and conditions of the task. Additionally, and in the presence of the IP, the student pilot was told that he would receive approximately ten minutes of "free flight" during which time the IP would provide instruction relevant to controls familiarization in addition to specific power setting cues and/or answers to the student's questions. During the free flight period, the IP required the student to practice all of the maneuvers he would be required to fly and participated in a continuous dialogue with the student essentially as the IP would do in an actual training flight. Following the free flight familiarization period, the sequence of randomized instrument and contact maneuvers was initiated. The IP was cautioned not to provide any instruction or feedback during the actual trials. At the close of each trial, the IP provided a rating of the overall maneuver using a scale of 1 (unsatisfactory) to 12 (excellent). The rating was communicated to the ASPT console operator via a private communication channel and was therefore unavailable to the student as a form of reinforcement or discouragement. The IP then provided general feedback in the form of comments directly to the student. At the completion of the 24-trial ASPT simulation task, the student pilot was debriefed by the experimenter regarding the purpose of the study and thanked for his participation.

CHAPTER 3

Results

Several analyses were performed for both the experimental laboratory task and the HRL/ASPT simulation task. The results are reported under appropriate subheadings in order to facilitate communication of the data. A minimum of interpretation is offered as an aid in the conceptual grouping of that data. The laboratory results will be conveyed first followed by the simulator results. For the laboratory task the overall sensitivity of the three groups is first evaluated by comparing values of d'. Individual d' scores were obtained by summing hit and false alarm rates across all stimulus values. Next, the most representative pitch and bank stimulus conditions are analyzed in terms of the percent correct discrimination accuracy of the three groups as a function of discrimination difficulty. For the simulation task, the two student groups (experimental and control) are compared across four discrete aircraft maneuvers. Multiple dependent measures were taken and they are analyzed via repeated measures multivariate analysis of variance.

Laboratory Task

It was expected that the performance of the student pilot group receiving the cognitive pretraining would be superior to the student control group in the experimental laboratory task. To assess the between-group differences, a measure of each subject's discrimination sensitivity; i.e., d', was computed from subject responses across all pitch and bank stimulus values. These data, subjected to a 3 (Group) x 2 (Attitude) x 2 (Sequence) repeated measures analysis of variance, confirmed the expectation. A main effect for Group $F(2,33) = 6.950$, $p < .005$ and Attitude, $F(1,33) = 10.203$, $p < .005$ was observed. A Newman-Keuls post hoc comparison on the group main effects indicated that the experimental student group performed significantly superior to both the student control and the IP groups. The student control and IP groups did not differ significantly. The Attitude main effect reflected greater discrimination accuracy in the bank than in the pitch condition. A reliable Group x Attitude interaction was detected wherein the experimental group performed significantly better in the bank condition than did either the IP or student control group, $F(2,33) = 6.994$, $p < .005$. The mean d' data are summarized in Table 1 and the analysis of variance (ANOVA) summary is found in Table 2.

To understand the differences in d' and to assess the discrimination accuracy of the three groups, percent correct responses were computed for each of the three levels of discrimination difficulty for what was believed to be the two most representative stimulus conditions; i.e., 0° Pitch and 0° Bank. In brief review, the discrimination levels, in descending order of difficulty are: $\pm 2°$, $\pm 4°$, and $\pm 6°$ for pitch; and, $\pm 5°$, $\pm 10°$, and $\pm 15°$ for bank. These data, presented graphically in Figures 1 and 2, were subjected to separate 3 (Group) x 2 (Sequence) x 3 (Difficulty) repeated measures analysis of variance.

In the pitch analysis, significant main effects were observed for Group, $F(2,33) = 5.233$, $p < .02$ and Difficulty, $F(2,66) = 74.234$, $p < .001$. A Newman-Keuls a posteriori analysis was conducted on the group means at the three discrimination levels. At the most difficult level, $\pm 2°$, the only significant difference detected was between the two student groups, wherein the experimental group performed better than the control group. For the $\pm 4°$, and $\pm 6°$ levels of difficulty, both the student experimental and the IP groups were reliably superior to the control group. The IP group did not differ significantly from the experimental student group. The Difficulty main effect is clearly attributable to the low percent correct responses for the

TABLE 1. d' VALUES COLLAPSED ACROSS SUBJECTS AND STIMULUS DISCRIMINATION VALUES

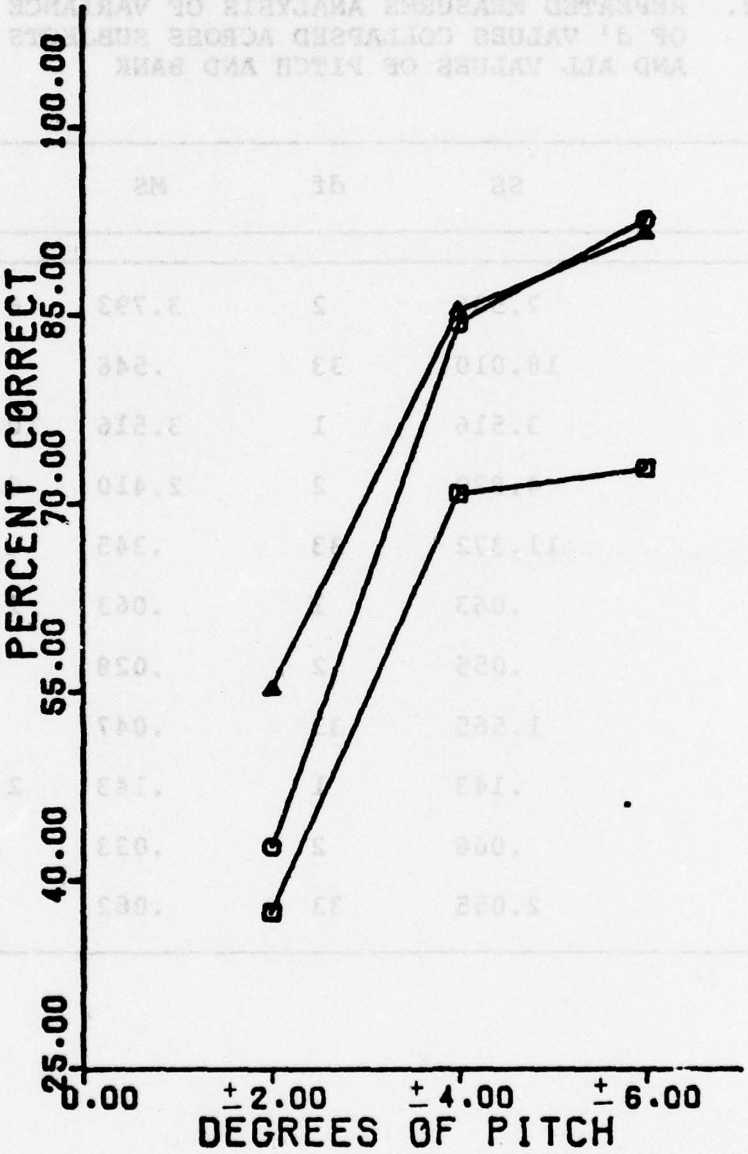
		(B_1) Pitch		(B_2) Bank	
Group	n	(C_1) I/C*	(C_2) C/I	(C_1) I/C	(C_2) C/J
(A_1) Experimental	12	1.114	.961	1.828	1.868
(A_2) Control	12	.790	.799	.972	.986
(A_3) Instructor Pilot	12	1.208	1.038	1.061	1.070

*I/C describes the task sequence, Instrument/Contact.

TABLE 2. REPEATED MEASURES ANALYSIS OF VARIANCE OF d' VALUES COLLAPSED ACROSS SUBJECTS AND ALL VALUES OF PITCH AND BANK

Source	SS	df	MS	F
A (Group)	7.586	2	3.793	6.950*
S/A	18.010	33	.546	
B (Attitude)	3.516	1	3.516	10.203*
A x B	4.820	2	2.410	6.994*
B x S/A	11.372	33	.345	
C (Sequence)	.063	1	.063	1.338
A x C	.055	2	.028	.581
C x S/A	1.565	33	.047	
B x C	.143	1	.143	2.297
A x B x C	.066	2	.033	.533
B x C x S/A	2.055	33	.062	

$^*p < .005$



▲ - Experimental

O - IP

□ - Control

Figure 1. Percent correct pitch discrimination as a function of discrimination difficulty.

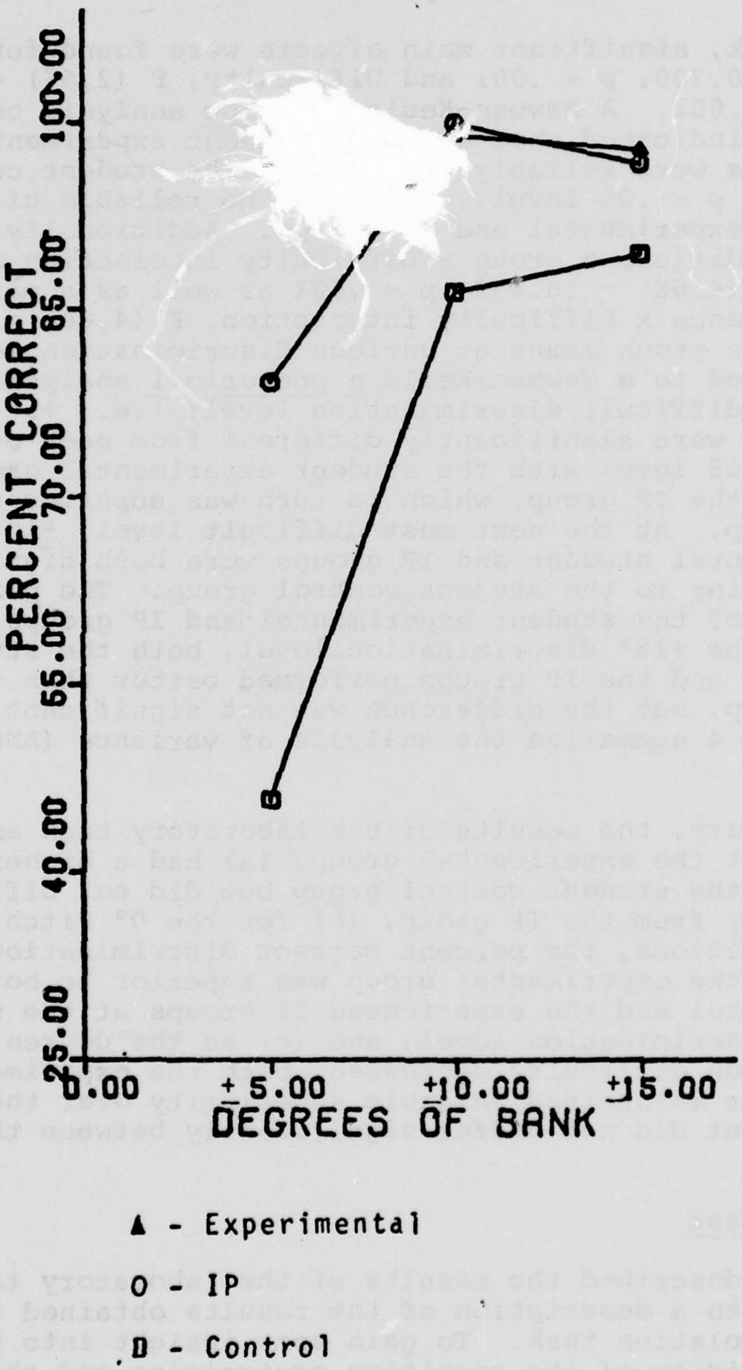


Figure 2. Percent correct bank discrimination as a function of discrimination difficulty.

most difficult; i.e., ±2°, discrimination. No additional significant differences were present.

For bank, significant main effects were found for Group, $F(2,33) = 10.700$, $p < .001$ and Difficulty, $F(2,66) = 32.770$, $p < .001$. A Newman-Keuls *post hoc* analysis on the group means indicated that both the student experimental and IP groups were reliably superior to the student control group at the $p < .05$ level. There was no reliable difference between the experimental and IP groups. Additionally, in the bank condition, a Group x Difficulty interaction was observed, $F(4,66) = 10.453$, $p < .001$ as well as a marginal Group x Sequence x Difficulty interaction, $F(4,66) = 2.870$, $p < .05$. The group means at various discrimination levels were subjected to a Newman-Keuls *a posteriori* analysis. At the most difficult discrimination level; i.e., ±5°, all three groups were significantly different from each other at the $p < .05$ level with the student experimental group superior to the IP group, which in turn was superior to the control group. At the next most difficult level, ±10°, the experimental student and IP groups were both significantly superior to the student control group. The performance level of the student experimental and IP groups were equal. At the ±15° discrimination level, both the student experimental and the IP groups performed better than the control group, but the difference was not significant. Tables 3 and 4 summarize the analysis of variance (ANOVA) results.

In summary, the results of the laboratory task analyses indicate that the experimental group, (a) had a higher overall d' than the student control group but did not differ significantly from the IP group, (b) for the 0° Pitch and 0° Bank conditions, the percent correct discrimination accuracy of the experimental group was superior to both the student control and the experienced IP groups at the more difficult discrimination level, and (c) as the degree of discrimination difficulty decreased, both the experimental and IP groups maintained reliable superiority over the control group but did not differ significantly between themselves.

Simulation Task

Having described the results of the laboratory task, we now turn to a description of the results obtained from the ASPT simulation task. To gain some insight into the external validity of the cognitive pretraining and the laboratory task, three trials of four aircraft maneuvers in each of two visual conditions were flown in ASPT. The

TABLE 3. REPEATED MEASURES ANALYSIS OF VARIANCE OF 0° PITCH CONDITION

Source	SS	df	MS	F
A (Group)	1.133	2	.566	5.233*
S/A	3.571	33	.108	
B (Sequence)	.019	1	.019	.523
A x B	.098	2	.049	1.372
B x S/A	1.175	33	.036	
C (Difficulty)	6.987	2	3.493	74.234**
A x C	.178	4	.045	.946
C x S/A	3.106	66	.047	
B x C	.098	2	.049	1.982
A x B x C	.046	4	.012	
B x C x S/A	1.627	66	.025	

*$p < .02$

**$p < .001$

TABLE 4. REPEATED MEASURES ANALYSIS OF VARIANCE OF 0° BANK CONDITION

Source	SS	df	MS	F
A (Group)	2.244	2	1.122	10.700**
S/A	3.460	33	.105	
B (Sequence)	.042	1	.042	2.253
A x B	.054	2	.027	1.441
B x S/A	.613	33	.032	
C (Difficulty)	2.119	2	1.059	32.770**
A x C	1.352	4	.338	10.453**
C x S/A	2.134	66	.032	
B x C	.002	2	.001	.055
A x B x C	.163	4	.041	2.870*
B x C x S/A	.939	66	.014	

*p < .05

**p < .001

maneuvers selected as being the most representative of the student's skill repertoire for their level of training were: (a) vertical-s-alpha, (b) straight-and-level, (c) turn-to-heading, and (d) steep-turn. Of the four maneuvers selected, all but the vertical-s-alpha, had been practiced repeatedly in the ground-based instrument simulator and all students had satisfied the maneuver proficiency requirements set forth in the instrument phase of training. For all ASPT maneuvers, multiple dependent measures in terms of RMS error scores and IP ratings were taken. Altitude, Airspeed, and IP ratings were constant dependent measures taken across all maneuvers. Heading scores were taken for all but the steep-turn while Bank scores were taken for steep-turn and turn-to-heading maneuvers only. Climb and descent Rate measures were taken for only the vertical-s-alpha maneuver. (See Table 5 for a summary of the maneuver relevant dependent measures.) Four separate 2 (Group) x 2 (Visual Condition) x 3 (Trials) repeated measures multivariate analyses of variance were computed. Generally, only significant multivariate results are reported unless specific *a priori* hypotheses predict given dependent variable effects (Finn, 1974).

In the analysis of the vertical-s-alpha maneuver, the experimental group performed significantly better than the control group, $F\ (5,18) = 4.513$, $p < .01$. It will be recalled that the vertical-s-alpha was the only maneuver of the four maneuvers flown that was novel to both groups. There were no significant between-group differences for the remaining three maneuvers. A main effect for Visual Condition for all four maneuvers indicated superior instrument performance over composite performance for both groups. The multivariate results are: for vertical-s-alpha, $F\ (5,18) = 13.057$, $p < .001$; for straight-and-level, $F\ (4,19) = 7.877$, $p < .001$; for turn-to-heading, $F\ (5,18) = 6.993$, $p < .001$; and finally, steep-turn, $F\ (4,19) = 9.220$, $p < .001$. A main effect for Trials was present for straight-and-level, $F\ (8,15) = 3.143$, $p < .05$ and for turn-to-heading, $F\ (10,13) = 2.833$, $p < .05$. These findings indicate a significant practice effect. No additional significant multivariate results were detected.

It was hypothesized that the experimental group would perform superior to the control group when compared across specific discrete dependent measures. For example, as a result of cognitive pretraining, it was believed that the experimental group would perform superior to the control group in Heading, Bank, and Rate. In light of these *a priori* hypotheses, the most important analyses are the univariate values within the Group main effects and the Group

TABLE 5. DEPENDENT MEASURES TAKEN PER MANEUVER

	Dependent Measure					
Maneuver	Altitude	Airspeed	Heading	Bank	Rate	IP Rating
Straight and Level	*	*	*[1]			*
Turn-to-Heading	*	*	*[2]	*		*
Steep Turn	*	*		*		*
Vertical-s-Alpha	*	*	*[1]		*	*

[1]RMS error scores in terms of deviations <u>from</u> a given heading.

[2]RMS error scores in terms of deviations of rolling out on a given heading.

x Visual Condition interactions. Inspection of the univariate values for the vertical-s-alpha maneuver indicates, as expected, reliable findings supporting the superior performance of the experimental group over the control group for Rate, $F\ (1,22) = 15.869$, $p < .001$; Heading, $F\ (1,22) = 10.498$, $p < .004$, and to a lesser extent, Airspeed, $F\ (1,22) = 6.207$, $p < .021$. The Group x Visual Condition interaction univariate terms are important in order to assess whether or not the between-groups difference is due to performance differences in both instrument and composite visual conditions or whether the differences are restricted primarily to one visual condition. A highly significant Group x Visual Condition univariate value for Heading, $F\ (1,22) = 10.124$, $p < .004$ supports our earlier hypothesis that the experimental group would perform better than the control group in the composite visual condition. For each of the straight-and-level and turn-to-heading maneuvers, the univariate between-group differences for Heading, favoring the experimental group, approached, but failed, to reach the traditional $p < .05$ level of significance. Inspection of all maneuvers revealed no significant univariate differences for Bank. An abbreviated summary describing the various multivariate findings can be found in Table 6. The interested reader is referred to the appendix for a complete MANOVA summary for each maneuver. (See Appendices A, B, C, and D.)

The results of the ASPT simulation task clearly demonstrates a performance decrement for both groups of student pilots when asked to fly familiar maneuvers while in a composite visual mode. These findings indicate that early training solely on instruments may result in the student pilot acquiring instrument tracking skills rather than an integrated network of skills based on internal (instruments) and external (horizon) information. The superiority of the experimental group suggests the utility of cognitive pretraining in facilitating the transition from instrument to composite flight.

CHAPTER 4

Discussion

The primary goal of the present study was to determine the role of cognitive pretraining as an aid in the transition from basic instrument to composite flying. The results of the pretraining, assessed by both the laboratory and simulation tasks, clearly support the effective role of cognitive pretraining in the early phase of pilot training. The improved discrimination accuracy of the experimental group in terms of pitch and bank was supported by parallel differences within the discrete maneuvers flown in ASPT.

TABLE 6. SUMMARY OF MULTIVARIATE RESULTS[4]

Maneuver	Source	F Value	p
Vertical-s-Alpha	Group Multivariate df=5,18	4.513	< .008
	Visual Condition Multivariate df=5,18	13.057	< .001
Steep-Turn	Visual Condition Multivariate df=4,19	9.220	< .001
Straight-and-Level	Visual Condition Multivariate df=4,19	7.877	< .001
	Trials Multivariate df=8,15	3.143	< .027
Turn-to-Heading	Visual Condition Multivariate df=5,18	6.993	< .001
	Trials Multivariate df=10,18	2.883	< .039

Overall, perhaps the most powerful effect demonstrated was the improved ability in discriminating shallow, i.e. +5° differences in bank from the wings level condition. This was indicated by the difference in heading performance between the two student groups. Instructor pilots, universally report that students naive to the T-37 flying phase of training consistently fly in a shallow 5° bank right turn during their early flying sorties. The IPs interpret this as the students' attempt to align the curved glare shield parallel to the horizon and to visually position the physical nose of the aircraft on the horizon rather than the conceptual nose. The effects of the cognitive pretraining appear to clarify and provide conceptual references that tie into the physical features of the cockpit. It is believed that this type of visual pretraining provides a rudimentary cognitive schema of the <u>view-from-the-cockpit</u>.

Providing prototype representation and deviations for straight-and-wings-level attitude, as well as 30°, 45°, and 60° left and right turns provides not only the central schema for a specific aircraft attitude but also assists the student in establishing the boundary conditions for those schemata.

One unexpected finding was the superior performance of the experimental group over the IP group in the laboratory task. There are perhaps three possible explanations for this finding. The first and most obvious is that the stimulus materials used, while initially confirmed as accurate representations, may have been sufficiently inaccurate to result in a decrement in experienced pilot performance. This view is unlikely, however, as the student experimental and the experienced pilot accuracy data were essentially equal for the least difficult and next to least difficult discrimination levels for both pitch and bank conditions. The control group leveled off at a much lower percent correct level. A second possible explanation for the difference may lie in the observation that the IP normally flies in the right seat of the aircraft and therefore may utilize different physical cockpit features when making attitude discriminations. Also, the IP does not have an attitude indicator and must glance across the cockpit to observe the student's attitude indicator. This is also unlikely as performance should have been suppressed across all levels of difficulty. A third possible explanation is that the experienced pilots, while once heavily dependent on external visual cues anchored within the physical features of the cockpit, have now transcended that cue dependence and utilize a more integrated visual and kinesthetic-based feedback repertoire. Further research is needed to evaluate the plausibility of this assumption.

We next turn to a discussion of more traditional approaches to pretraining, from which follows a brief discussion of schema theory and its relationship to the present research. Generally, investigators interested in the effects of pretraining have traditionally been concerned with questions regarding transfer of training. A variety of transfer designs have been utilized, depending on the type of questions asked. Several transfer paradigms are designed to probe the extent to which stimulus-response factors influence positive, negative, and even zero transfer conditions. With these types of transfer designs the stimulus and response components are typically manipulated such that same and different stimuli are paired with same and different responses. The interested reader is referred to Ellis (1972) for a readable review of the major transfer paradigms. A form of stimulus-response or S-R training relevant to the present research is that of stimulus predifferentiation. In the stimulus predifferentiation paradigm, the stimuli are presumably made less confusing and/or more distinctive during training. Arnoult (1957) in a review of a number of stimulus predifferentiation studies concluded that the results of such studies were largely influenced by the kind and amount of verbal pretraining utilized. His review focused on relevant and irrelevant S-R designs as well as a directed attention design. A major point in Arnoult's review was his observation that in studies utilizing attention pretraining, performance equalled relevant S-R performance in 50 percent of the studies compared! These findings are of considerable importance in that studies utilizing directed attention, the subject is merely instructed to attend to the differences in distinctive features. In the present study, the cognitive pretraining contained a major directed attention component. There were, however, sufficient differences in the content and sequence of the pretraining to prevent placing the present design solely within the directed attention paradigm. For example, both the content and the sequence of pretraining materials were directly manipulated from (a) the labeling of relevant cockpit features, to (b) the conceptual use of those labels to form brief verbal descriptors, to (c) the extension of those verbal descriptors to simple perceptual rules regarding visual attitude, to, finally, (d) the provision of a number of physical generations of the prototypical attitude to facilitate discrimination. It is believed that this conceptual approach assisted the student pilot in developing a cognitive representation, or schema, of the "view-from-the-cockpit."

The concept of schema, or schemata, is not new and those interested in the early use of the concept are referred to Bartlett (1932), Oldfield (1954), and Oldfield

and Zangwill (1942, 1943). Evans (1967) acknowledging that schema theory is neither fully developed nor a rigorous system, offers two brief but appropriate definitions. He suggests: "A schema is a characteristic of some population of objects. It is a set of rules which would serve as instructions for producing (in essential aspects) a population prototype and object typical of the population....A schema family is a population of patterns generated under the same rules."

Attneave (1957) in the second of two reported experiments, demonstrated that pretraining on a prototype of a geometric shape, positively influenced recognition performance of distortions of the prototypical geometric shape in a subsequent task. He also pointed out that pattern recognition was enhanced by knowledge of the variability limits of the pattern. Posner and Keele (1968) studying human abstractions of visual information found that subjects receiving pretraining on stimuli, describing a broad range of variability compared favorably in transfer performance with subjects receiving pretraining on say just the prototype. Several investigators (Franks & Bransford, 1971; Homa, Cross, Cornell, Goldman, & Swartz, 1973; Homa & Vosburgh, 1976) studied the abstraction of prototypical information and confirmed the hypothesis that training on a broad range of category exemplars aids learning and retention. These theoretical studies while somewhat peripheral to the applied nature of this research serve to point out the importance of schemata in perception.

Vernon (1955), in an earlier paper, reviewed the relationship between schemata and perception. She suggests that schemata, operating within a perceptual framework, assist the perceptual process by first, producing a condition of expectation within the observer where he knows what to look for and is therefore facilitated in his ability to discriminate signal from noise; and, second, sets up within the individual the knowledge of how to deal with the incoming information. That is, how to label, classify, interpret, and draw meaning from the incoming data. It is as if the schemata serve somehow as advance organizers with which to efficiently and effectively assimilate information. With these assumptions, the acquisition of task relevant perceptual schemata would presumably reduce the memory or information processing load in a given complex task. Indeed, Evans (1967) reporting within the context of schema theory, advances the supposition that humans abstract or otherwise eliminate redundant information to reduce the information processing and memory storage requirements of the task.

Cognitive pretraining appears to offer a sound and economical approach to many aspects of flying training research. The concept of a schema places less emphasis on fixed S-R chains and presumably more emphasis on the development of flexible and adaptive skills. Additionally, the supposition put forth by Evans (1967) that operational schemata serve to reduce processing load suggests a fertile area of research regarding flying training. For example, how does the notion of schema tie in with the observation by DeMaio, Parkinson, and Crosby (in press) that experienced pilots appear to be able to peripherally detect instrument errors in a visual scanning task where student pilots do *not*? Does this suggest a lower processing load for those individuals possessing the schema for instrument reading? Little is known theoretically regarding the form or locus of schemata. Additional research is needed to understand questions dealing with the apparent facilitative role of schemata in the acquisition of complex cognitive and perceptual-motor skills such as those required in flying high-performance aircraft.

REFERENCE NOTES

[1]For the straight-and-level and vertical-s-alpha maneuvers, RMS error scores are deviations from an initial and constant heading.

[2]RMS error scores for the turn-to-heading maneuver are deviations from a desired heading the subject was instructed to turn to.

[3]The two univariate values for each dependent measure are the results of the Helmert contrasts. The first value is the significance of the comparison of Trial 1 to the average of Trials 2 and 3. The second value is the comparison between Trials 2 and 3.

[4]Multivariate tests of significance using Rao's approximation to Wilks lambda criterion.

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APPENDIX A

Complete MANOVA Summary for Vertical-S-Alpha

Source	F Value	p
Group		
Multivariate df=5,18	4.513	< .008
Univariate df=1,22		
Altitude	.441	< .513
Airspeed	6.207	< .021
Heading	10.498	< .004
Rate	15.869	< .001
IP Rating	2.675	< .116
Visual Condition		
Multivariate df=5,18	13.057	< .001
Univariate df=1,22		
Altitude	3.023	< .096
Airspeed	2.631	< .119
Heading	45.464	< .001
Rate	11.241	< .003
IP Rating	20.838	< .001
Group x Condition		
Multivariate df=5,18	2.033	< .122
Univariate df=1,22		
Altitude	.007	< .935
Airspeed	.315	< .581
Heading	10.124	< .004
Rate	.086	< .772
IP Rating	2.383	< .137
Trials[3]		
Multivariate df=10,13	2.184	< .094
Univariate df=1,22		
Altitude	.832	< .372
	.020	< .888
Airspeed	18.143	< .001
	3.941	< .060
Heading	5.376	< .030
	.701	< .412
Rate	9.940	< .005
	.984	< .332
IP Rating	17.842	< .001
	.884	< .357

Source	F Value	p
Group x Trials		
Multivariate df=10,13	.638	< .759
Univariate df=1,22		
Altitude	.620	< .440
	.153	< .700
Airspeed	.830	< .372
	.002	< .970
Heading	.006	< .938
	.616	< .441
Rate	.020	< .889
	.029	< .866
IP Rating	.469	< .501
	1.571	< .223
Condition x Trials		
Multivariate df=10,13	1.037	< .466
Univariate df=1,22		
Altitude	.537	< .472
	1.661	< .211
Airspeed	1.850	< .188
	1.825	< .191
Heading	.994	< .330
	1.589	< .221
Rate	.108	< .745
	.650	< .429
IP Rating	.131	< .721
	.631	< .436
Group x Condition x Trials		
Multivariate df=10,13	2.155	< .098
Univariate df=1,22		
Altitude	.003	< .957
	.296	< .592
Airspeed	18.932	< .001
	.062	< .806
Heading	.133	< .719
	.213	< .649
Rate	.300	< .590
	.027	< .872
IP Rating	5.549	< .028
	.280	< .602

APPENDIX B

Complete MANOVA Summary for Steep-Turn

Source	F Value	p
Group		
Multivariate df=4,19	.148	< .962
Univariate df=1,22		
Altitude	.330	< .572
Airspeed	.155	< .698
Bank	.080	< .780
IP Rating	.023	< .881
Visual Condition		
Multivariate df=4,19	9.220	< .001
Univariate df=1,22		
Altitude	5.477	< .029
Airspeed	8.989	< .007
Bank	38.843	< .001
IP Rating	8.751	< .007
Group x Condition		
Multivariate df=4,19	.490	< .743
Univariate df=1,22		
Altitude	1.405	< .249
Airspeed	1.793	< .194
Bank	.185	< .672
IP Rating	1.013	< .325
Trials[3]		
Multivariate df=8,15	1.958	< .125
Univariate df=1,22		
Altitude	.499	< .488
	.312	< .582
Airspeed	.897	< .354
	.040	< .844
Bank	2.399	< .136
	.882	< .358
IP Rating	3.462	< .076
	.037	< .850
Group x Trials		
Multivariate df=8,15	.918	< .529
Univariate df=1,22		
Altitude	.166	< .688
	2.025	< .169
Airspeed	.554	< .465
	.077	< .784

Source	F Value	p
Bank	.818	< .376
	.009	< .925
IP Rating	.001	< .973
	.693	< .414
Condition x Trials		
Multivariate df=8,15	.749	< .650
Univariate df=1,22		
Altitude	.730	< .402
	.610	< .443
Airspeed	.731	< .402
	.602	< .446
Bank	.005	< .943
	.203	< .657
IP Rating	.213	< .649
	.090	< .767
Group x Condition x Trials		
Multivariate df=8,15	1.002	< .473
Univariate df=1,22		
Altitude	.018	< .894
	.230	< .636
Airspeed	3.218	< .087
	2.751	< .112
Bank	.469	< .501
	.009	< .927
IP Rating	.102	< .753
	.292	< .595

APPENDIX C

Complete MANOVA Summary for Straight-and-Level

Source	F Value	p
Group		
Multivariate df=4,19	1.677	< .197
Univariate df=1,22		
Altitude	1.125	< .300
Airspeed	2.776	< .110
Heading	3.287	< .084
IP Rating	1.352	< .257
Visual Condition		
Multivariate df=4,19	7.877	< .001
Univariate df=1,22		
Altitude	3.813	< .064
Airspeed	3.809	< .064
Heading	31.295	< .001
IP Rating	24.788	< .001
Group x Condition		
Multivariate df=4,19	.887	< .491
Univariate df=1,22		
Altitude	.552	< .466
Airspeed	.428	< .520
Heading	.309	< .309
IP Rating	.699	< .699
Trials[3]		
Multivariate df=8,15	3.143	< .027
Univariate df=1,22		
Altitude	18.184	< .001
	1.015	< .325
Airspeed	.052	< .821
	.028	< .869
Heading	6.033	< .023
	1.220	< .281
IP Rating	19.382	< .001
	.360	< .555
Group x Trials		
Multivariate df=8,15	.439	< .880
Univariate df=1,22		
Altitude	.075	< .787
	.007	< .934
Airspeed	.110	< .743
	.328	< .572

Source	F Value	p
Heading	.185	< .671
	.659	< .426
IP Rating	.080	< .780
	.007	< .933
Condition x Trials		
Multivariate df=8,15	1.264	< .331
Univariate df=1,22		
Altitude	1.677	< .209
	.520	< .478
Airspeed	.143	< .709
	1.471	< .238
Heading	8.003	< .010
	.450	< .509
IP Rating	4.925	< .037
	.302	< .588
Group x Condition x Trials		
Multivariate df=8,15	.512	< .829
Univariate df=1,22		
Altitude	.308	< .585
	.025	< .877
Airspeed	.152	< .700
	.119	< .733
Heading	1.147	< .296
	2.158	< .165
IP Rating	.002	< .964
	.592	< .450

APPENDIX D

Complete MANOVA Summary for Turn-to-Heading

Source	F Value	p
Group		
Multivariate df=5,18	.869	< .521
Univariate df=1,22		
Altitude	1.448	< .242
Airspeed	1.115	< .303
Heading	3.688	< .068
Bank	.075	< .786
IP Rating	3.664	< .069
Visual Condition		
Multivariate df=5,18	6.993	< .001
Univariate df=1,22		
Altitude	13.284	< .002
Airspeed	13.134	< .002
Heading	32.452	< .001
Bank	2.413	< .135
IP Rating	16.260	< .001
Group x Condition		
Multivariage df=5,18	.886	< .511
Univariate df=1,22		
Altitude	1.003	< .328
Airspeed	.260	< .615
Heading	.447	< .511
Bank	1.348	< .258
IP Rating	2.574	< .123
Trials[3]		
Multivariate df=10,13	2.883	< .039
Univariate df=1,22		
Altitude	13.047	< .002
	.268	< .610
Airspeed	4.431	< .047
	.225	< .640
Heading	5.164	< .033
	4.084	< .056
Bank	.656	< .427
	.528	< .475
IP Rating	24.593	< .001
	.075	< .787

Source	F Value	p
Group x Trials		
Multivariate df=10,13	2.021	< .117
Univariate df=1,22		
Altitude	4.671	< .042
	.910	< .351
Airspeed	.066	< .800
	.614	< .442
Heading	.701	< .412
	.043	< .837
Bank	1.591	< .221
	.141	< .711
IP Rating	7.873	< .010
	.019	< .892
Condition x Trials		
Multivariate df=10,13	1.575	< .219
Univariate df=1,22		
Altitude	.731	< .402
	.482	< .495
Airspeed	3.209	< .087
	.040	< .844
Heading	.940	< .343
	3.432	< .077
Bank	.285	< .599
	1.431	< .244
IP Rating	.594	< .449
	.921	< .348
Group x Condition x Trials		
Multivariate df=10,13	.593	< .794
Univariate df=1,22		
Altitude	.731	< .402
	2.444	< .132
Airspeed	.741	< .399
	1.064	< .314
Heading	1.120	< .302
	.651	< .429
Bank	2.147	< .157
	3.527	< .074
IP Rating	.470	< .500
	1.879	< .184

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